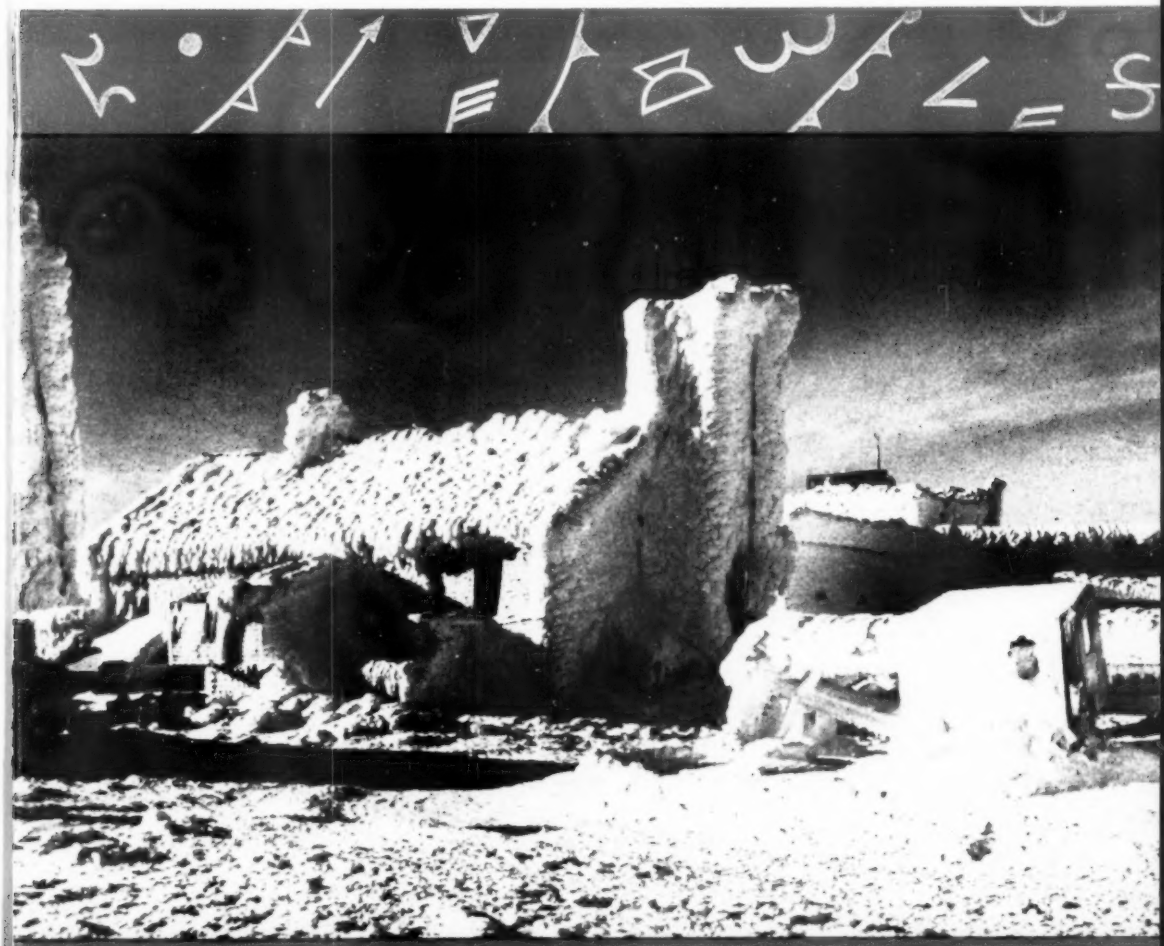
Weatherwise



Volume 9, Number 5 October 1956

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

AMS CALENDAR — 1956–57

Asheville, N. C.	Conference on Climatology	29 October–1 November
New York City	With American Association for the Advancement of Science	28–31 December
New York City	Annual Meeting	28–31 January
Chicago, Ill.	General Meeting and Conference on Hydrometeorology	19–21 March
Cambridge, Mass.	6th Weather Radar Conference	26–28 March
Kansas City, Mo.	Conference on Severe Storms	16–18 April
Chicago, Ill.	Session on Bioclimatology with Federation of American Societies for Experimental Biology	19 April
Washington, D. C.	With American Geophysical Union	29 April–3 May
St. Louis, Mo.	With Air Pollution Control Association	3–7 June
Monterey, Calif.	General Meeting	10–12 June
Omaha, Neb.	Conference on the Upper Air	8–10 October
College Station, Tex.	General Meeting	13–15 November

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Cover: The Mount Washington Observatory building after the Ice Storm of January 1956. Photo by Arthur Bent.

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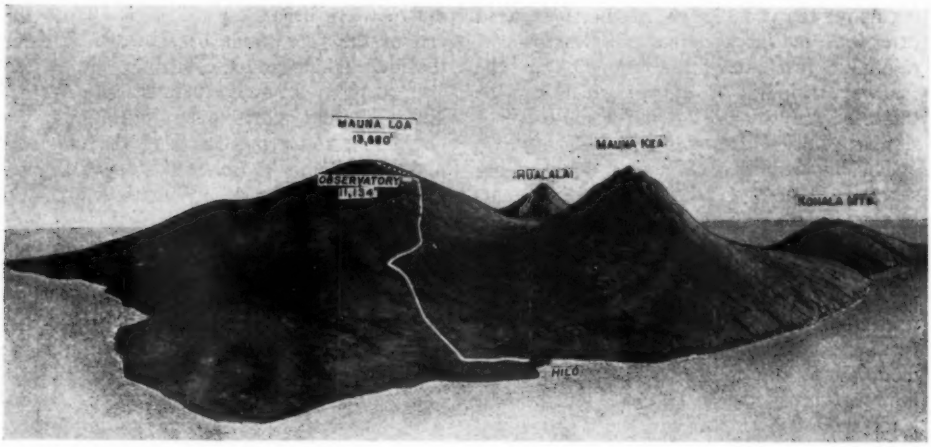


A model constructed by the University of Hawaii of the Island of Hawaii. The winding trail from near Hilo to the "slope" observatory station may be seen, as well as the trail to near the summit. Vertical exaggeration about 4 to 1. USWB photo.

The Mauna Loa Observatory

Roy L. Fox, *Meteorologist in Charge, Pacific Supervisory Office, U. S. Weather Bureau, Honolulu, Hawaii*

THE National Bureau of Standards and the Weather Bureau, two agencies in the United States Department of Commerce, have recently completed a new addition to the Mauna Loa Observatory. This facility, to be operated by the Weather Bureau and designated as the "slope" unit of the Observatory, is situated 11,134 feet above sea level on the north slope of the large volcanic mountain, Mauna Loa, often referred to as the mightiest single mountain mass in the world. It is situated 2,319 feet lower than the small unit of the Observatory erected near the summit of this mountain in 1951.

The basic components of the recent addition are: a 20 by 40 foot functional and pleasant-looking concrete block structure, partitioned into three bedrooms, a combined kitchenette and dinette, and a combination work shop and laboratory room; a 15 by 45 foot ground-level concrete pad for the basing of instruments and an elevated wooden observing platform; and two instrument and antenna towers. The facility is powered with two diesel generators and possesses its own electrical lighting system, as well as a Butane gas range, hot water heater, refrigerator, and space heater. It also has its own water catchment system and water storage and distribution plant.

It is accessible by passenger vehicles over a gradual grade, crushed-lava and volcanic-cinder roadway which leads westward up the mountain from the main highway running south out of Hilo, the principal city on the Island of Hawaii, the largest and southeasternmost island in the Hawaiian chain. This roadway to the summit leads first through several miles of dense tropical rain forest with its profusion of tree ferns, Ohia and Koa trees, and many other varieties of vegetation typical of warm humid tropical climates, thence through thinning trees and shrubs, and then up and out onto the strikingly patterned lava wastes which cover the upper reaches of this mighty mountain. Ly-

ing above the usual height of the trade wind inversion, the upper area experiences light rainfall. Just above the "slope" unit the roadway dwindles to a trail which can be traversed only by use of four-wheel drive or similar vehicles, and this with difficulty.

The importance of Mauna Loa as an observatory site first received world-wide attention in scientific circles in 1920 when the First Pacific Science Congress, meeting in Honolulu, adopted a resolution recommending the establishment of a weather station at its summit. This action helped to highlight the importance of this large, gentle sloping mountain as an observatory site. It was not, however, until the late 1940's, under the leadership of R. H. Simpson, the Weather Bureau's Meteorologist-in-Charge, Pacific Area, that definite plans for a Mauna Loa Observatory began to take shape. There followed quick and decisive action by scientists, legislators, engineers, surveyors, governmental administrative officials, and highway and building construction people. A small building, the first "summit" unit of the Observatory, was completed in late 1951 following construction of the roadway to just above the 11,000-foot level and a trail above that point.

Instruments were installed and an observing program was initiated at the summit location. Equipment for recording wind speed and direction, temperature, humidity, rainfall, and pressure were utilized at the "summit" site from the beginning, with visits made to service them and to obtain their records once every three to five weeks. At three points scattered along the roadway leading up the slope of the mountain, hygrothermographs and recording rain gages were also installed. As time passed, it became evident that operation at the "summit" unit would have to be suspended because of the great difficulties encountered in climbing the trail above 11,000 feet and in late 1954 regular trips to the 13,453-foot level were discontinued. Observations with weekly or biweekly visits, however, did continue at the lower slope points, one of which was at an elevation of 10,958 feet above sea level.

In 1955 more attention was focused on the significance of Mauna Loa as an active observatory site, and plans for erecting the "slope" building and for furnishing and outfitting a combined observing facility and living quarters began crystalizing. Before the end of the year funds became available for the undertaking and the planning progressed even further. In early 1956, the site was acquired, building plans and specifications were developed, and construction of the unit was undertaken and completed. The structure was equipped and partially instrumented, and on 28 June 1956 it was dedicated.

Although it is planned ultimately to man the unit on a continuous basis and to carry on several types of uninterrupted observations and studies from this site, only limited meteorological observations are now being made continuously, most of these through the use of recording instruments. Other types of observations are, for the present, on a short duration "project" basis by groups who arrange with the Weather Bureau for the use of the facilities.

The first group to use the Observatory was a National Geographical Society party of four headed by Dr. C. C. Kiess, a staff member of the National Bureau of Standards. This party used the site for a spectrographic study of the atmosphere of the planet Mars during the period in early July of this year, when the planet was rapidly approaching closer to the earth than it has been in many years. Other short-duration special group studies are also being planned for the immediate future. One, tentatively scheduled for this coming winter, concerns the structure of snow crystals formed under natural conditions in an atmosphere containing few aerosols, and a second involves solar radiation measurements.

Being higher than the usual level of the trade wind inversion in the general area of the Hawaiian Islands, the Observatory is above much of the atmospheric moisture for a good portion of the time. Because of Mauna Loa's location far from large dry continental land masses and industrial sites, the atmosphere around and above the Observatory is also substantially free of dust particles and contaminants. The turbidity of the air at the site is usually so low that visibility is exceptional.

An outstanding climatological feature of the Observatory "slope" site and of the summit is the mild and equitable temperatures experienced the year 'round. As shown by the accompanying table, the mean tempera-

AVERAGE TEMPERATURES AT THE TWO OBSERVATORY LOCATIONS

	"Summit" location			"Slope" location		
	Average maximum	Average minimum	Average temperature	Average maximum	Average minimum	Average temperature
Jan.	39.3	23.5	31.4	47.7	30.1	38.9
Apr.	39.1	24.2	31.7	52.6	32.8	42.7
July	47.4	31.8	39.6	56.3	35.4	45.9
Oct.	44.3	28.8	36.6	57.1	36.9	47.0

Figures are degrees Fahrenheit.
Averages are based on extremely short and unequal periods of record.

ture around the 11,000-foot level for July is 45.9° F., while that for January is 38.9° F., both based on only a few years of records. The situation is similar at the 13,453-foot "summit" site where the average July temperature is 39.6° and the average January temperature 31.3°. The highest temperatures ever recorded at the two sites are 57° for the summit and 68° for the immediate vicinity of the "slope" unit. Correspondingly, the lowest temperatures are 16° and 20° respectively. Snow falls only occasionally at the summit and seldom outside the cooler half of the year, November through April. It falls even less frequently at the lower of the two sites. Seldom is the snowfall heavy enough to block the trail between the two points, but occasionally during the coolest portion of the year it may remain in the unmelted state but for only a few days at a time. Hail occurs infrequently in thunderstorms at both places.

Although the annual fall of moisture at the two Observatory sites is relatively low, there is a marked contrast in annual rainfall amounts at various elevations along the northeast slope of Mauna Loa. This is depicted quite graphically in figure 3.

At Hilo, which lies on the northeast coast of the Island at the juncture of Mauna Loa's slope with the sea, the annual rainfall is 140 inches, approximately two and a half times that of Miami, Florida, or New Orleans, Louisiana. At a point near 3,000 feet above sea level on a straight line course to the "slope" unit, the annual rainfall exceeds 240 inches, nearly four times that of Miami or New Orleans. But at the new Observatory facility it is around 18 inches, just slightly

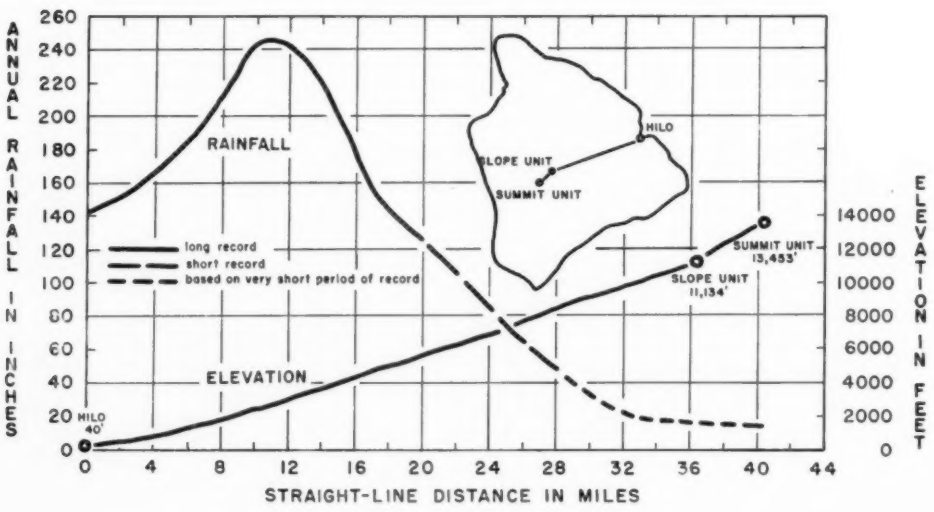
The recently completed Mauna Loa "Slope" building. Weather instruments at left. Altitude is 11,134 feet.

greater than that at Los Angeles, California, or Denver, Colorado. The annual fall of moisture at the "slope" unit is only about 13 per cent of that at Hilo and less than 8 per cent of that at the 3000-foot level on the "straight line" course, yet these points are all on the face of the mountain exposed to the east northeast, the prevailing direction of the trade winds in this area of the globe.

This rainfall pattern along a more or less straight line on one face of a large gently sloping mountain is a testimony to two opposed processes. The orographic lifting of the air in the trade wind flow as it strikes the mountain from the east northeast results in the higher rainfall at 3,000 feet than at sea level. The other feature accounts for the approximate 220-inch decrease in annual rainfall amounts between points at approximately 3,000 feet and 11,000 feet above sea level and the low yearly amounts from the 11,000 foot level to the summit of the mountain. It is the capping action of the trade wind inversion which serves to trap moisture and hold it below 11,000 feet above sea level, for the greater part, if not all, of each day.

Mild and relatively equitable temperatures, low annual rainfall, good visibility, usually light winds, and relative freedom from atmospheric contaminants are not the only environmental features which enhance the value of the "high level" Mauna Loa Observatory for many types of observations. It is far enough up the mountain to remain, on many days, above the trade wind cloud deck which builds up almost daily along the mountain's northeast slope due to daytime heating of the lava fields. Low clouds may build to this height at times, though seldom before 1100 do they reach to the "slope" unit and they usually recede by 1700 or 1800.

It is expected that the buildings of the Mauna Loa Observatory will be used during the years to come by many scientists whose studies will contribute substantially to man's storehouse of knowledge in various fields of geophysics. When the improved road can be extended to the summit and a more appropriate facility erected there, comprehensive observations and studies will be carried on at that point also. The "slope" unit will then serve as a staging point and living quarters for the scientists who will commute to the summit on a day-to-day basis.



Elevation and rainfall distribution along Mauna Loa's northeast slope.

The Mt. Washington Observatory

CHARLES F. BROOKS, *President, Mt. Washington Observatory*

THE first regular meteorological observations on the summit of Mt. Washington in northern New Hampshire were made during the summers from 1853 to 1859 by Nathaniel Noyes. Round-the-year observations commenced in November 1870 when an expedition, organized by Prof. C. H. Hitchcock and led by Prof. J. H. Huntington, both of Dartmouth College, occupied the summit. The U. S. Signal Corps cooperated in this undertaking and assumed full responsibility for the station from May 1871, operating it as a year-round station until the fall of 1887 and thereafter only in summers. The United States Weather Bureau took over the work of the Signal Corps in 1891 and finally closed the station completely the following year. In the summers of 1905–07 S. P. Fergusson operated a meteorograph on the summit, while flying aerological kites from the village of Twin Mountain.

Twenty-five years later conditions became auspicious for a revival of meteorological activity on Mt. Washington. Joseph B. Dodge, the U. S. Weather Bureau cooperative observer at the east base of the Mountain, had a keen personal interest in knowing what might be happening on the 6,288-foot summit which towered 4,200 feet above his location; the International Meteorological Organization was calling for observations at mountain stations during the Second International Polar Year, 1932–33; the Blue Hill Meteorological Observatory of Harvard University had a surplus of meteorological instruments that it would be glad to loan for the purpose; the New Hampshire Academy of Sciences was willing to grant $400; the Mt. Washington auto road company agreed to allow its stage office to be used to house the observatory; capable volunteers were available; and many individuals and organizations wished to contribute in cash or in kind. So the Mount Washington Observatory was organized and observations started in November 1932. The observations were so interesting and useful that the Observatory has continued ever since, with essential assistance

The Mt. Washington Observatory building looking from the north. Yankee Network TV antenna at rear. Photo by C. F. Brooks.

from the Weather Bureau after 1936. Since 1937 the Observatory has been housed in a building constructed for it by the Mt. Washington (Cog) Railway Co.

The Weather Bureau had observers of its own at the Observatory from 1936 to 1951, but from 1952 has paid the Observatory for making and transmitting the observations.

The Observatory is a Voluntary Corporation, organized in 1936 under the laws of the State of New Hampshire, supported by membership dues and contributions—"To make, summarize and report scientific observations, chiefly geophysical, in the vicinity of Mount Washington, New Hampshire; to conduct radio studies on Mount Washington; and to further public safety and public appreciation of scientific work on Mount Washington."

The present officers are: Charles F. Brooks, President; Maj. Gen. C. F. Bowen, Retd., Vice-President, and Joseph B. Dodge, Secretary-Treasurer. Mr. Dodge is also Managing Director. The Board of Trustees includes the officers and Messrs. Alan C. Bemis, Raymond G. Lavender, Livingston Lansing, Irving B. Meredith, James J. Storrow, and Wallace E. Howell.

The present work of the Observatory consists of: (1) complete 3-hourly synoptic and local airways weather reports, day and night, which are transmitted by radio to Portland, Maine, for teletype transmission to much of the Northeast; (2) research in cloud seeding, including sublimation nuclei counts at 3-hourly intervals; (3) studies of snow crystals with respect to their use as aerological sondes; (4) atmospheric electricity, at both summit and base; (5) collection of cloud water for radioactivity assessment; (6) cosmic ray counts; (7) weathering of panels; (8) snow surveys; (9) public education; and (10) mountain safety. Half-a-dozen nonresident scientists direct a mountain-top staff of five men who are headed by Kenneth T. Elder.

The current project in cloud seeding is nearly finished. "Operation Overseed" has been carried on for a year by project director Roland J. Boucher and the Mountain staff, in cooperation with field director Robert B. Smith of the Advisory Committee on Weather Control. The main effort was to determine attenuation of massively produced silver iodide "smoke" with distance, under various conditions of temperature lapse-rate and wind. Strongly convective situations were found to dissipate the smoke very rapidly; inversions would hold the smoke below. Silver iodide was measured indirectly on the summit both through the variations in the numbers of sublimation nuclei, as revealed by crystallization in a deep-freeze box, and through the effect of the silver iodide in reducing the liquid water content of a cloud on the summit, as indicated by the rotating, multicylinder rime-collector.

"Project Snowflake," under a U. S. Signal Corps contract, comprises an attempt to determine from the types of snow crystals and their changes during the course of a storm what changes in temperature and water content of the air are in progress overhead.

Precipitation gages on rugged terrain west of the Observatory. Gages have wind shields and tilt slightly toward the west according to the surface slope. Photo by C. F. Brooks.

Replicas are made in Formvar at frequent intervals for post-storm photographing under the microscope and for subsequent comparison with synoptic changes. Scientific director Joachim P. Kuettner, project analyst Boucher, and former chief observer Rudolf A. Honkala have been responsible for the progress of this study. The results from the first winter's work show a definite relation between snow crystal type and synoptic changes overhead. It is expected that replicas will be obtained at the base of the Mountain as well as at the summit next winter to find out what changes in crystal form take place during a fall of 4,200 feet, mostly, if not entirely, through cloud.

Routine collections of cloud water are being made for the Weather Bureau on behalf of the Atomic Energy Commission for analysis as to the presence of radioactive strontium.

The variations in atmospheric electric potential gradient are being continuously recorded both at the summit and the base of Mt. Washington, in an effort to find out what causes the variations. The most prominent factor is atmospheric pollution, but others, as yet unidentified, are involved. The Munitalp Foundation has been sponsoring this project with research associates Arthur E. Bent and Prof. Huntington W. Curtis working on the data.

Cosmic ray counts are being recorded automatically for a University of New Hampshire project under the direction of research associate Prof. John A. Lockwood. This undertaking has been in operation for several years under the sponsorship of the U. S. Air Force. As we approach the maximum in the current sun spot cycle with increasing solar output, the work is becoming increasingly exciting.

The weathering of variously coated panels outdoors is being determined for the Marshall Research Laboratory of the du Pont Company. Annual snow surveys are made for the Rumford Falls Power Company. Public education is carried on by means of a *Mt. Washington News Bulletin,* which is published under the editorship of Arthur E. Bent, by miscellaneous publications, by displays in a "goofer" room at the Observatory which some 10,000 persons visit every summer, and by twice-daily one-minute telecasts over WMTW-TV on the summit. Public safety is promoted by the active participation of members of the Observatory crew in rescue or fire suppression operations when they are occasionally needed on the exposed upper-half of the Mountain, and also by serving as a radio relay point at time of off-mountain disasters such as airplane crashes, severe storms, or floods.

The Observatory cooperates in various ways with all other units occupying the summit and provides a base of operations for visiting scientists or engineers with temporary projects requiring the cold or windy conditions of Mt. Washington for tests. Among these are: "Project Summit," operated by Smith, Hinchman and Grylls, under contract with the U. S. Air Force and various manufacturers of jet engines; the Mt. Washington Railway Co., The Mt. Washington Summit Road Co., the Appalachian Mountain Club, Mt. Washington TV, the Quartermaster Corps, and Dartmouth College (present owners of the summit).

The climate of Mt. Washington is its greatest asset, because of the combination of coldness, liquid fog, and super-hurricane wind speeds on frequent occasions. These conditions naturally intrigue the man on the street in the warmer and more sheltered lowlands, but they also serve a direct and useful purpose in the development of aircraft, to provide both against wing and propeller icing and against ice closure of jet-engine intakes, and in the development of cold weather clothing. Furthermore, the day-to-day weather shows continuously what is going on at middle levels. This is a useful supplement to the 12-hourly rawinsondes in the general Weather Bureau network. The times of arrivals of warm and cold fronts on the summit, and, eventually aloft, through applications of our snow crystal techniques, can be determined and usefully applied in forecasting. The changes in weather at this level are also of current interest to all aviation in the vicinity.

The accompanying table for the twenty years, 1933–1952, gives some of the more prominent features of the climate.

The wind, pressure, and precipitation equipment necessary for obtaining a record on Mt. Washington differs from their lowlands counterparts. For wind, the usual cup anemometer is employed when no rime ice is forming and when the wind is not over 100 miles per hour. Under other conditions

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature (° F)													
Average	6	5	12	22	35	45	50	48	41	31	20	9	27
Abs. max.	44	42	48	60	63	71	70	71	65	59	50	45	71
Abs. min.	−46	−46	−38	−18	−1	8	28	24	11	−5	−19	−46	−46
Precipitation (inches)													
Av. precip.	4.9	4.6	5.6	6.0	5.5	6.4	6.2	6.3	6.8	5.5	6.6	6.3	70.7
Av. snowfall	26	25	27	25	9	1	T	0.1	2	9	24	30	178
Wind (miles per hour)													
Average	50	48	45	39	33	29	26	24	29	35	41	48	37
Max 5 min.	154	144	180	188	164	136	110	110	136	161	150	173	188
Peak gust				231					189		160		231
Frequencies (number of days)													
Min. temp. ≤32°	31	28	31	29	19	6	1	3	12	24	29	31	244
Max. temp. ≤32°	29	27	26	18	6	1	0	0	2	10	21	28	168
Min. temp. ≤0°	17	17	11	2	0	0	0	0	0	0	4	14	65
Dense fog (in cloud)	23	25	26	24	23	26	26	26	24	25	26	26	300

which exist more than half the time of each winter, an electrically-heated, pitot-static, air speed indicator is kept pointed to the wind by means of a heated wind vane. Even then, an aquarium pump must keep a weak reverse flow of desiccated air moving out through the pitot head in order to prevent clogging of the tubes with water and ice. The wind speed is registered in terms of inches of water pressure on a Hays draft recorder. The apparatus has been described by J. H. Conover in the *Bulletin of the AMS*, December 1951.

The atmospheric pressure representative of the free air at the height of the Mountain can be obtained only by factoring out the venturi effect of the wind in passing through the space narrowed by the presence of the mountain. The resulting lowering of the pressure is proportional to the square of the speed. This can be nicely compensated for, as Raymond E. Falconer showed in the *Transactions of the American Geophysical Union*, April 1947, by attaching the barometer and the barograph to the impact head of the pitot-static anemometer, since the pressure at the head of the anemeter is increased in proportion to the square of the wind speed.

The precipitation, to be caught at all, must be surrounded by a wind-diverting shield, and the can must be at least three feet deep. Otherwise, either the snow will never have a chance to fall into the gage; or, if it has entered, it will be whisked out again in the tremendous winds that often accompany precipitation. The flaring top of the shield and the top of the orifice must also be placed at an angle parallel to the general slope of the surface where it is exposed. Even these concessions to the special conditions on a windy mountain do not take care of the catch of drifting snow, which varies both with wind and snow condition. Sometimes it has to be estimated. We can only hope that the increased catch of drift snow in a stronger wind compensates roughly for the decreased catch of falling snow under such conditions.

Readers who want more details about the Observatory and its climate are invited to become members of the corporation. The dues are $1 per year.

The Climax Observing Station of the High Altitude Observatory, University of Colorado, as pictured in July. Snow covers ground, often 12 feet deep, from mid-October to early June.

A High Altitude Solar Research Station

WALTER ORR ROBERTS, *High Altitude Observatory of the University of Colorado, Boulder and Climax, Colorado*

THE best weather pattern for an observatory devoted to research on the sun's halo, the corona, is an improbable amalgam of opposites: cloudlessly clear sky and regular, gentle rain or snow. Moreover, such corona-gazing requires the atmospheric purity generally found only at high altitudes.

No location in the United States, to the best of my knowledge, fulfills these needs in an ideal way. Several approach it, including Sacramento Peak in New Mexico and the site of the High Altitude Observatory at Climax, Colorado.

Observers at the Climax station constantly exploit the combination of weather opposites as they take observations of the sun's corona without natural eclipse—which is the central goal of research at the High Altitude Observatory.

The corona, so clearly visible during an eclipse, is quite invisible at other times with ordinary telescopes. Yet because daily changes in the corona may be high significant for man's understanding of the sun, continuous coronal observation has been a long-time goal of astronomers, a goal not reached

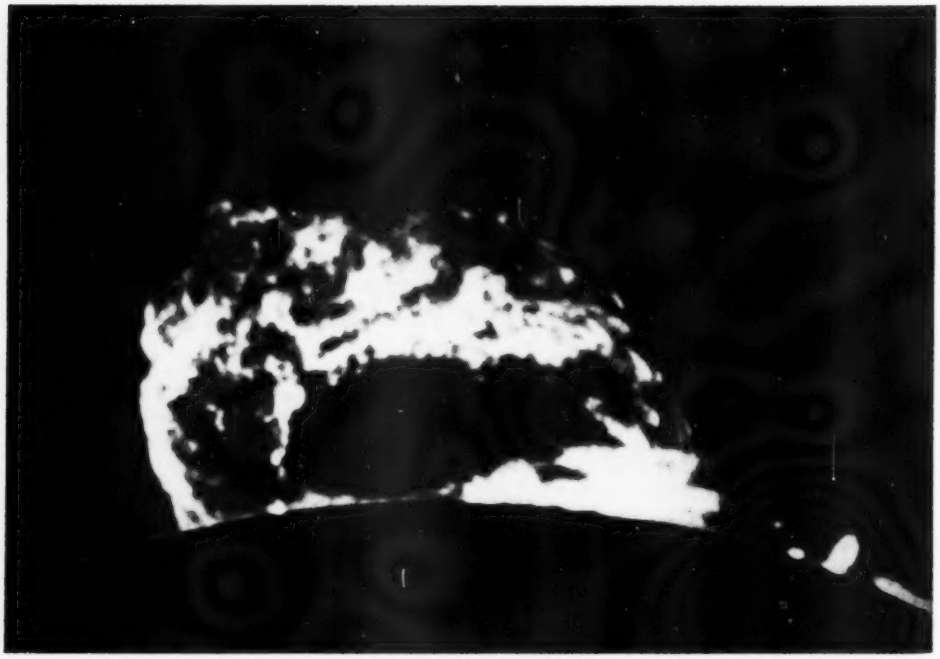
until the invention of the coronagraph in 1930.

To observe the sun's corona from day to day one must use this very specialized form of telescope, known as a "Lyot coronagraph" in honor of its distinguished inventor, the late Dr. Bernard Lyot of the Paris Observatory.

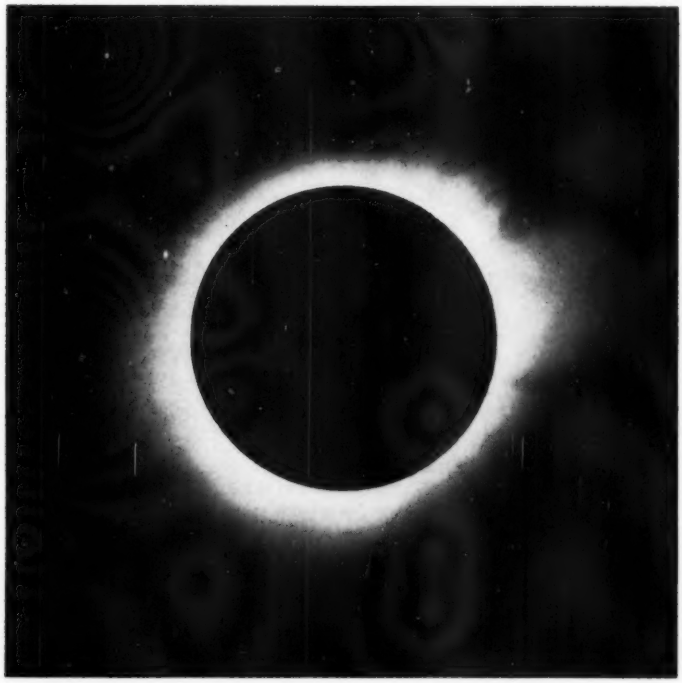
In simplest principle the coronagraph is easy to understand. Its first lens produces a solar image that is eclipsed by a steel "occulting disk." Light from past the edges of the occulting disk passes through the secondary optical elements to the film or spectrograph. The secondary optical elements are the intricate ones; and their function is essential. They are the elements that eliminate the diffraction and reflections of the light from the sun's bright face, without impeding the image of the coronal halo. The result is a unique instrument that can photograph the majestic and mysterious corona, with its complex structure and its slowly-varying day-to-day changes.

But the coronagraph is also an instrument that can, like the spectroheliograph, photograph the mercurial and far more brilliant solar prominences, whose explosive violence can be shown graphically in time-lapse motion picture sequences. Prominences and corona hold locked up within them many of the mysteries of the sun's far ultraviolet radiation and of its electrified particle ejection. These emissions in turn are the key to a host of sun-earth effects in radio communication, cosmic rays, earth magnetism, and perhaps even in large-scale atmospheric circulation.

To succeed, a coronagraph must have the advantage of a transparent sky, utterly free from dust, ice, or water droplets that might produce a screening atmospheric halo and overwhelm the corona and prominences. If you hold your hand at arm's length, and eclipse the sun with one finger, you can generally see a bright atmospheric halo around the sun. But if you can see no halo whatso-



An eruptive solar prominence photographed with the coronagraph at Climax. The High Altitude Observatory analyzes the temperatures, densities, velocities, and other properties of solar outbursts. These will help to solve many weather, radio, and upper atmospheric problems.



The sun's corona as seen at eclipse. Photo courtesy of the U. S. Naval Observatory, Washington, D. C.

ever and the sky is clear blue right to the very edge of the sun, then the sky is likely to be sufficiently clear to permit the operation of a coronagraph. And so it very often is at Climax.

My first view of the Climax site is one I shall not forget. I had come, in the summer of 1940, as a just-married graduate student at Harvard College Observatory, to man the brand-new solar research station created by Dr. Donald H. Menzel, who is now director of the Harvard Observatory. Janet and I were Easterners, far Easterners, and the Colorado Rockies staggered us—to say nothing of our dilapidated Graham-Paige automobile with its load of household and scientific gear. The last 100 yards to the still-unfinished observatory were steep, winding, and narrow to flatland eyes. The house and observatory, perched on a small ridge just east of the Climax Molybdenum Company mining community at an altitude of 11,520 feet above sea level, seemed indeed remote and forbidding.

Later, of course, I came to regard the road, which *did* receive modest improvements, as entirely reasonable and the location near the attractive mining community as quite civilized; a wonderful place in which to live, to start a family—and above all to do research.

The elements of altitude, precipitation and clear sky dominate the lives of the three observers at the present Climax station, now four miles away from its original spot in a more isolated but more spacious sub-alpine meadow. The altitude assures a substantial percentage of clear, dust-free sky at times of clear weather. It also sets limits on such things as the physical exercise, sleep and cooking habits of the people who must operate the scientific instruments. The atmospheric pressure is only two-thirds the sea level value, water boils at 190° F, and visitors often wish they had oxygen masks. With the altitude goes also the severity of climate one normally associates with the Arctic—the endlessly long winters, the strong winds, the deep snow, and the isolation.

(Continued on page 177)

This is the third of a series of six articles which will appear in forthcoming issues of *Weatherwise*. Each article will discuss the prevailing tracks of highs and lows for the two months following the publication month.

Prevailing Tracks of Lows and Highs

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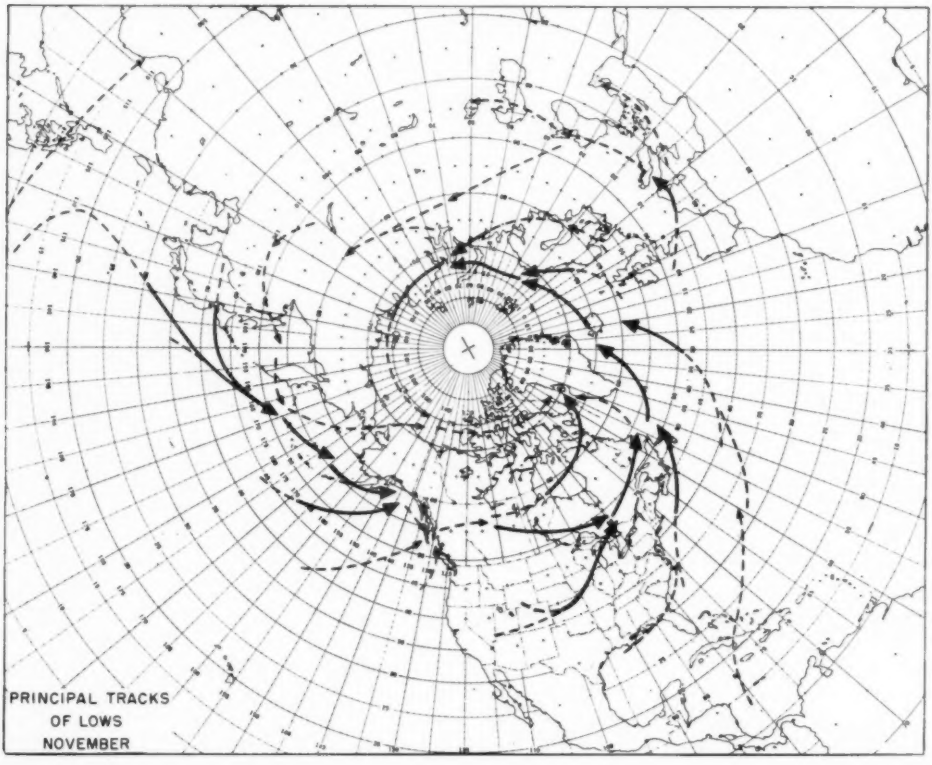
Principal tracks of cyclones and anticyclones at sea level. The prevailing direction of motion of systems is indicated by the arrows. Heavy solid lines denote primary tracks—those which are most frequent and generally indicated by various data sources; thin dashed lines denote secondary, less frequent, and less well defined tracks. All arrow heads end in areas where cyclone frequency is a local maximum. Here the tracks may cross, branch, and merge, although not specifically so drawn. Locally preferred regions of genesis are indicated where secondary or primary tracks begin, whether in centers of maximum cyclone frequency or elsewhere. An area of frequent genesis is also indicated when a single secondary track changes to a single primary track or when two secondary tracks merge to form a primary track, with a break between dashed and solid lines.



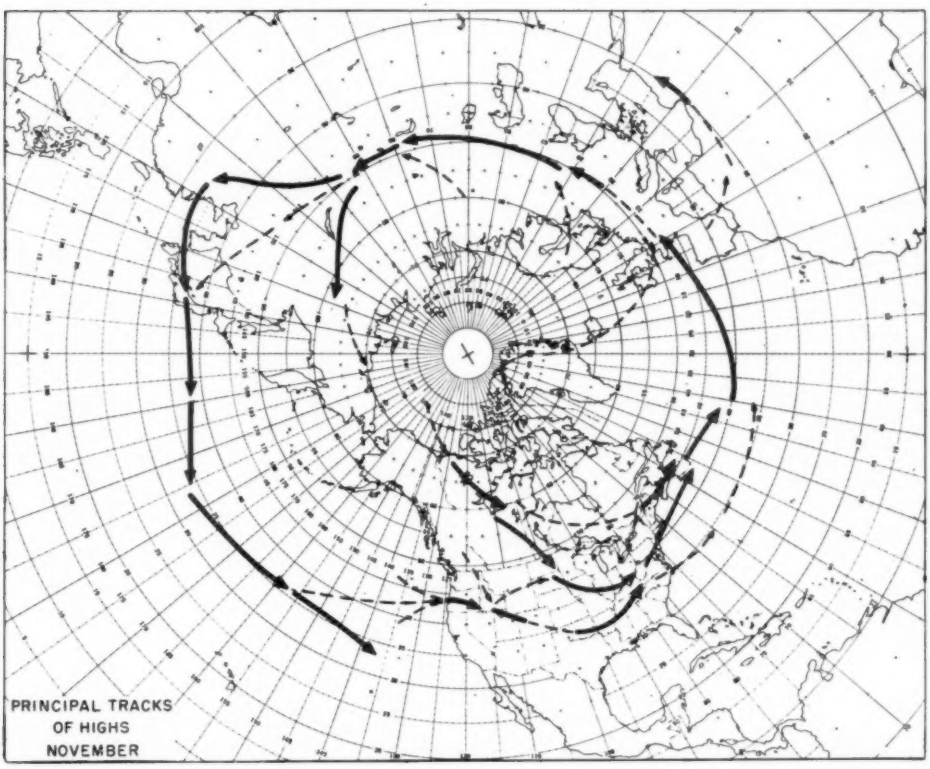
November Cyclones

SEVERAL features of the storm tracks which are characteristic of the winter months appear in November. For example, in the eastern Pacific three new paths lead into a secondary center of maximum cyclone frequency off the coast of British Columbia. One of these originates in the Gulf of Alaska, an area where, in November and in five of the following six months, there are more lows per unit area than any other part of the Northern Hemisphere. Another notable feature of November that is typical of the cold season is the convergence of two primary storm tracks, composed of Alberta and Colorado lows, into a center of maximum cyclone frequency around the Great Lakes.

In the Atlantic the primary track shifts from the east to the west side of Iceland. A center of maximum cyclone frequency is now found in the Denmark Strait, where it remains during the next five months. Additional tracks which appear in November and intensify during winter are those through the northern Gulf of Mexico, eastern Mediterranean, Caspian Sea, and Sea of Japan. Otherwise the principal cyclone paths of November are quite similar to those of October. However, some southward displacement is evident in the primary track in southern Canada. A southward shift also occurs in the latitude of recurvature of tropical storms, which diminish in frequency in all sectors.

November Anticyclones

During November the majority of anticyclone tracks take on typical wintertime characteristics. In North America the meridional track of polar highs in western Canada becomes of primary importance for the first time since March. Most of these highs move southeastward through the central United States along a well defined path which is now definitely south of the Great Lakes. As in



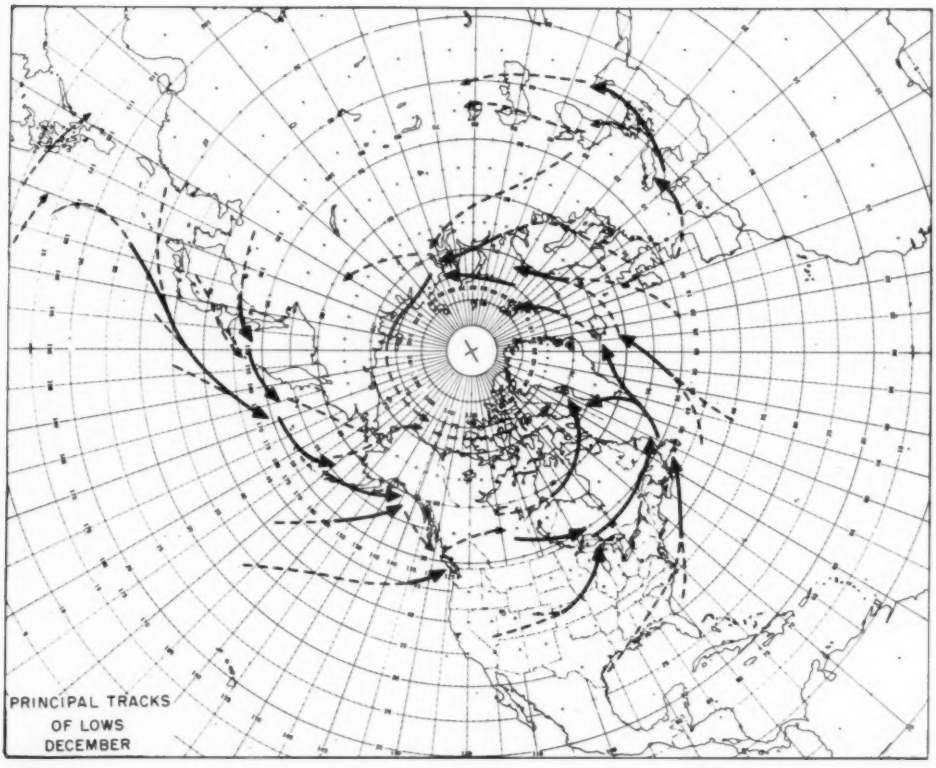
winter, some of these Canadian highs travel north of the Lakes, through Ontario and Quebec, before passing out to sea through Maine and the Maritime Provinces. Wintertime properties also appear in the Great Basin, where frequency of both anticyclones and anticyclogenesis are the highest in the hemisphere for November, and a pronounced center of high pressure appears on the normal sea level map. Most of the Basin highs move through the southern United States on a course which merges with the primary track of polar anticyclones in the Appalachian area.

Continued southward displacement of the principal anticyclone tracks during November is responsible for their more wintry appearance in the Eastern Hemisphere. The October route in the Mediterranean Sea is now completely over land, in North Africa. In East Asia the primary track passes south of Korea and the Sea of Japan, and anticyclonic passages become more frequent in northeast Siberia.

On the other hand, some of the anticyclone tracks during November retain the aspects of fall and even summer. This is particularly true in the Atlantic, where the primary track is located between 40° and 45° N each month from June through November. Two unique characteristics of the fall months are: first, the presence of a primary anticyclone path from West Virginia northeastward along the southern New England coast; and second, the merger of the tracks of some Basin and polar highs in the northern Plains. Other tracks of November, which are prevalent during fall but disappear in winter, are those from Greenland into Great Britain and from Lake Baikal into the Sea of Japan.

December Cyclones

December is a month of great cyclonic activity in many parts of the world. During this month more lows per unit area are found in the Gulf of Alaska than in any other part of the Northern Hemisphere during any other



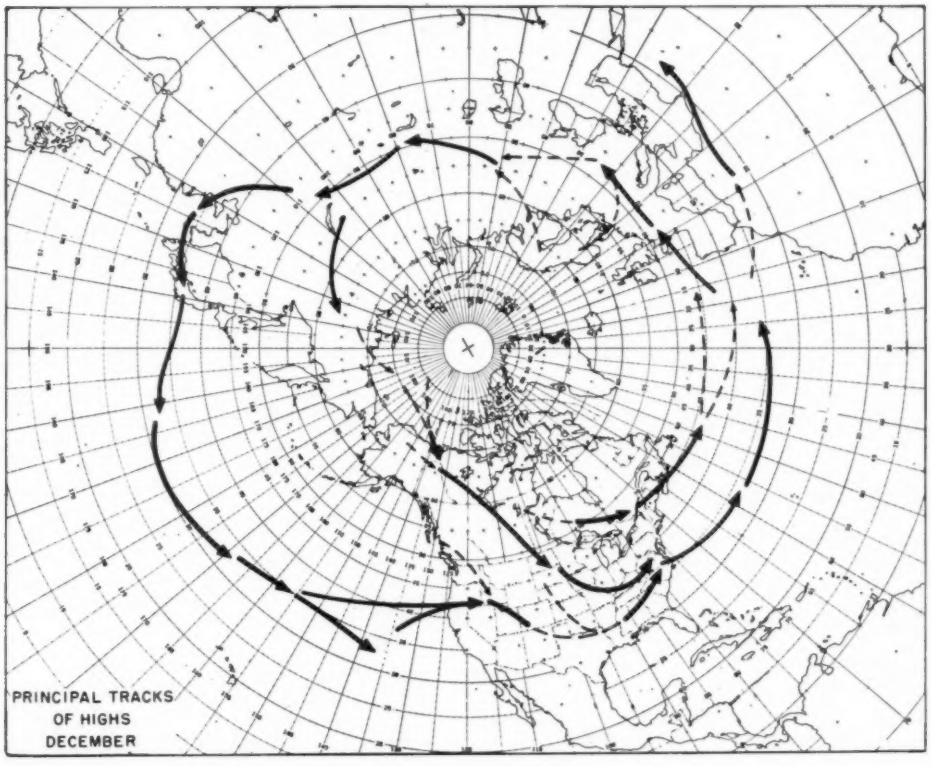
month of the year. Other stormy regions which have their highest cyclone frequency of the year during December include the Great Lakes, Barents Sea, Iceland, and Spitzbergen. In addition, the Aleutians, Davis Strait, and Italy experience their second highest frequencies. Finally, the frequency of cyclogenesis in the Gulf of Mexico reaches its annual maximum in December.

Many of the principal storm tracks and associated centers of maximum cyclone frequency are farther south in December than November. This southward displacement is noticeable around Manchuria, the Sea of Okhotsk, the eastern Pacific, British Columbia, Newfoundland, and the Balkans. Increased cyclonic activity at lower latitudes results in the appearance of new tracks through the Caspian and East China Seas and the conversion of a secondary to a primary route in the eastern Mediterranean. The incidence of tropical cyclones diminishes sharply in all sectors in December, and only the typhoons of the western Pacific are still sufficiently frequent to warrant inclusion as a secondary storm track.

December Anticyclones

During December the last vestiges of the fall anticyclone pattern disappear. Prominent among these are the tracks of November from the Great Basin into the Northern Plains, from West Virginia to southern New England, from Greenland to England, and from Lake Baikal through Manchuria. On the other hand, certain features appear which are found during the winter months only. These include the Pacific track located as far south as 30° N; and secondary paths of polar highs from the Dakotas into Texas, from Alaska into the Yukon, and from northeast Siberia into the Arctic Ocean. Other new aspects of the December anticyclone tracks are typical of spring as well as winter, including a secondary from the eastern At-

(Continued on page 177)



Two observers free the Observatory tower of its tremendous ice load after the storm. Photo by Gordon M. Pugh; courtesy Arthur Bent.

The Great Ice Storm, 8-13 January 1956

RUDOLF A. HONKALA, *Chief Observer, Mt. Washington Observatory*

JANUARY 1956 saw Mt. Washington lashed by a storm which was, if not the most severe ice storm in the history of observed weather on the mountain, then one that must be reckoned with the worst. I have just finished reading Vic Clark's report on the ice storm of December 1945 which, at that time, was termed the "worst one of its kind in eight years and more probably in the 14-year history of the Observatory." Using that storm as a basis for comparison, our most recent storm must be considered as the worst experienced by Mt. Washington Observers.

The six-day storm brought with it 5.29 inches of precipitation in the form of snow, sleet, freezing rain, freezing drizzle, rain and drizzle. Only 3.9 inches of frozen precipitation fell during the period. The temperature ranged from 17–34 degrees and the wind reached velocities of 121, 123, and 93 miles per hour respectively for the 8th, 9th and 10th. While winds of these speeds are not uncommon on the mountain, in combination with the aforementioned elements, the results were appalling. Ice, clear blue ice, built out very rapidly on all exposed surfaces. Even now, 1 March, the snow cover on the upper reaches of the mountain is suffering because of the storm. The hard smooth ice persists, and newly fallen snow blows away quickly leaving us with only a few small snow fields as of March 1st.

The storm began with snow at 0515, on the 8th, the snow changing to freezing drizzle at 0830. The wind increased steadily, averaging in the 80's that evening and through most of the day following. I chanced to be at Pinkham Notch on the morning of the 9th listening to Joe Dodge's early morning radio contact with the summit. Scott Cooledge reported that the Observatory crew was frozen in, the ice making it impossible for the staff to open any door to the outside. It did not appear that transportation would be avail-

The terrain of Mt. Washington on Five Mile Stretch and Air Force Sno-Cat, which carries supplies and personnel to the summit. Photo by Arthur Bent.

able to the summit, but on the chance that some vehicle would be going up, I went to the Glen House, the starting point of the Mt. Washington auto road. Phil Labbe showed up shortly thereafter, and in spite of rather heavy rain the WMTW-TV Snowcat made the trip to the summit in rather uneventful fashion. We encountered freezing rain at a point just below 7 mile mark on the road, at 5,500 feet above mean sea level. The doors had been opened by the time we arrived, but the storm continued.

On the evening of the 9th, after surveying the situation, it was deemed impractical to continue attempts to de-ice the whole of our tower. Ice was forming at such a rate that only the wind vane and the pitot tube could be kept clear. Winds reached 123 m.p.h. from the SE at 1925 that evening; sleet and freezing rain continued to fall. On the evening of the 10th, though conditions in the tower were extremely treacherous, it was felt that some of the ice would have to be removed from the pipe railings in the tower. It took four men, working in shifts, over two hours to remove the bulk of the ice from the pipes in the tower. The ice on the windward sides of the buildings ranged in thickness from 15–18 inches near the ground to a thickness of an estimated 6 feet at the upper edge of the tower. A 6 foot upright in the tower carried a monstrous burden, the ice surrounding this pipe was approximately 2 feet thick at the top increasing to a thickness of 3–4 feet at its base, while the build-out windward was about 3 feet at the top increasing to some 6 feet at the base. The piece was chopped away in one chunk, estimated in weight as about 900 lbs.

In spite of the heavy icing and high winds, damage to installations was limited, due largely to the fact that little of the ice fell from the buildings. Most of it remains where it was deposited. A small section of roof on the TV installation was damaged by ice falling from the TV antenna. Damage to the Observatory installation was in the form of smashed railings in front of the building. One railing was smashed during the storm, the other by ice that had to be chopped away from the tower for protection of life and limb. It was an uneasy feeling, walking out of the front door when literally tons of ice clung to the tower. Mac Palmer, with assists from Brook Vivian and Willie Harris, was roped down from the top of our tower and with the help of an ice axe, was able to loosen the tremendous accumulation of ice from the front of our building. It was a difficult time, a fantastic storm, an experience we'll long remember.

An ice-sealed entrance-way atop the mountain after the ice storm.

A record snow cover towers above the parking area at Mt. Baker Lodge at 4,150 feet in the Cascades of northwest Washington. Weather Bureau recorded 384″ snow depth in vicinity of trees in background on 30 March 1956. USWB photo.

Snowflakes as Question-Marks

JAMES K. MCGUIRE, *Northeast Area Climatologist, Weather Bureau Office, New York City*

AN ancient joke about the weather exists in a variation that may be briefly (and mercifully) told as follows. Three strangers meet and begin boasting about their local climates. The Minnesotan brags that he is used to long winters, "but they bring dry cold, so it doesn't bother anyone." In turn, the Arizonian lauds his summers, with their "dry heat, that is most comfortable." And, to top them both, the Down-Easter laconically praises Maine's "dry snow, which is a real free treat."

Readers of *Weatherwise* have probably heard that one before. Its repetition here is justified not for its "dry" humor but for the moral it contains. Whatever may be true of temperature, there is no such thing as dry snow. All snow represents water. This simple fact, however, gives rise to a series of difficulties and problems. These are very familiar to anyone who has tried to measure cold-season precipitation. And yet, another discussion of the factors involved in making an accurate record of snowfall, water equivalent, and snow depth seems in order: the subject is that important. For weather observers in many parts of the nation, be they cooperative, amateur or professional, have to deal with snow every winter, and upon their reports depend the conclusions that are drawn about one of our most valuable climatic resources.

Of course, in a relative sense, we all speak of dry and wet snow. The well-known "10-to-1 ratio" is commonly regarded as the dividing line between the two types. In other words, a density of 10% is taken as average. Snow is thus considered to be moist when it melts down to more than one-tenth of its frozen amount, and to be dry when its water content is less. For example, a two-inch fall that yields 0.30 of an inch of water is called wet, but termed dry if it gives only 0.10 of an inch.

The 10-to-1 ratio has also been used to estimate the water equivalent of snow from an observation of snowfall amount. This application of the 10% density average has a long history. In the United States the practice dates back officially to 1875. Earlier, the assumption was recognized although its use was not authorized in the instructions to observers. The U. S. Signal Corps Weather Service (precursor of the civilian Weather Bureau) first followed the Smithsonian instructions in this regard, but in the above-mentioned year added the provision:

> Whenever from any cause snow cannot be melted, the depth will be measured and 10 inches of snow recorded as 1 inch of rainfall (1).*

In subsequent revisions of the pertinent instructions, under both the Signal Service and the Weather Bureau, cooperative observers have been repeatedly urged to measure the water equivalent of snow by either of two suggested procedures. The 1/10 average ratio is permitted to this day, however, as a sort of last resort, although mention of it has been dropped from the current edition of *Instructions for Climatological Observers* (2).

What is wrong with this venerable method? From a general point of view, it is fairly satisfactory if the principle be accepted that the estimate it gives is better than no report at all. Examined closely, it becomes much less satisfactory. The trouble is the fact that the 10% density assumption may lead to large errors. In an article published last February in the *Weekly Weather and Crop Bulletin*, Walter T. Wilson of the Hydrologic Services Division of the U. S. Weather Bureau summarized recent research on the subject. As he remarked, the article illustrates "some of the problems of observing a weather element that one might think offhand to be very simple and straightforward." On the 10-to-1 ratio, he states:

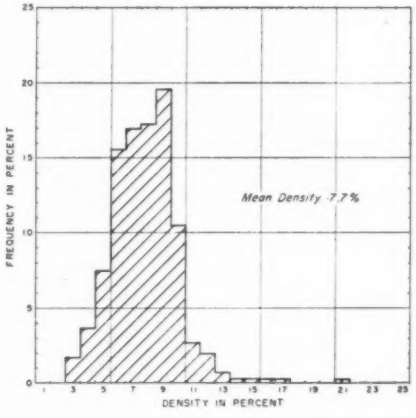
> The salient fact in this whole problem is that the density of new-fallen snow is seldom 10 per cent. The average density at some stations is less than 7 per cent and at others is more than 12 per cent. At most stations, the density commonly varies from 3 per cent for some storms to as much as 30 per cent at others (3).

This conclusion was based on an analysis of the snowfall records of stations all over the United States. It is therefore significant, because the objection might otherwise be raised that 10% is a good average density for most of the country, a lower figure being expected from northern and mountain observation points and a higher figure from southern and coastal locations. Figure 1, which is reproduced from Wilson's article, shows that even at Burlington, Vermont, however, a 10% density-average is too high.

This fact is also shown in Table 1, derived from a fifteen-year record of snow measurements at Potsdam, Germany (4). Notice that the 10-to-1 ratio gave fair results only in February, but was about 9–12% in error during November, December, and January and over 20% too low in March.

The problem is complicated by additional factors.

FREQUENCY DISTRIBUTION OF NEW-FALLEN SNOW AT BURLINGTON, VERMONT, 295 SNOW STORMS, 1919–1948.



* Numbers in parentheses refer to references at end of article.

TABLE 1

MEASURED VS. COMPUTED (BY 10-TO-1 RATIO) WATER EQUIVALENTS OF SNOWFALL DURING 15 WINTERS AT POTSDAM, GERMANY

Month	Water equivalent of snowfall		Differences	
	Measured, inches	Computed, inches	Inches	Per cent
November	4.40	3.89	−0.51	−11.6
December	3.03	3.31	+0.28	+ 9.2
January	8.31	9.06	+0.75	+ 9.0
February	5.50	5.42	+0.08	+ 1.4
March	4.85	3.82	−1.03	−21.2

Although snow density will vary widely from storm to storm at any given station, there is a general seasonal variation, such that it is least in midwinter and greatest at the beginning and ending of the snow season, as may be seen from Table 2 (5). It is based

TABLE 2

AVERAGE DENSITY (1910–1916) OF FRESH SNOW AT WAGON WHEEL GAP, COLO.

Month	Average density	Inches of snow to 1 inch of water
September	0.100	10
October	0.098	10
November	0.081	12
December	0.071	14
January	0.077	13
February	0.082	12
March	0.081	12
April	0.098	10
May	0.131	7.6

on measurements made during six winters at Wagon Wheel Gap, Colorado. This station had an elevation of 9,500 feet and the winter precipitation was entirely in the form of snow.

This seasonal variation of snow density introduces the related question, how is the density of snowfall related to the concurrent surface air temperature? The answer is simple: it is practically impossible to classify snowfall according to this relationship. Of course, a sort of correlation does exist in the same sense as does the seasonal variation, from which it may be deduced. That is, when snow begins to fall in late autumn and early winter, the air temperature is ordinarily higher than in midwinter, and the density varies similarly. From the same data used for Table 1, Wengler (6) obtained the temperature-density relationships that are presented in Table 3. The chief limitation of

TABLE 3

SURFACE AIR TEMPERATURE VS. SNOWFALL DENSITY, 15 WINTERS, POTSDAM, GERMANY

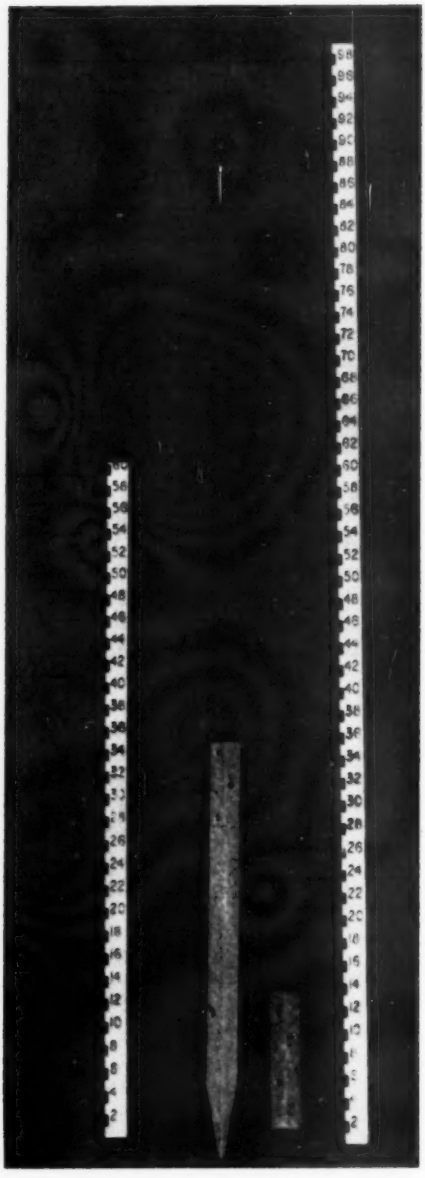
Temperatures (°F)	Density
Under 14	0.046
14–23	.082
23–27	.086
27–30	.089
30–32	.103
32–34	.140
34–37	.235

this table, and the reason why it is extremely difficult to determine the relationship involved, is the fact that with temperatures above freezing it is practically impossible to exclude those cases in which the snowfall is mixed with rain. Hence Table 3 is presented merely for what it is worth, which is truthfully not much.

The above discussion referred exclusively to new-fallen snow. Now, it is not always possible to measure the snowfall immediately upon its ending. Cooperative observers often wait until their regular time of observation which may be several hours after the fall has ceased. This delay complicates the density-depth relationship even more. As Wilson remarks,

> Usually the density of a new layer of snow increases rapidly, starting immediately after its deposit. For example, a fall of snow early some evening might have an initial density of 8 per cent, but by the time it is measured the following morning, settlement and other density-increasing processes would typically have increased the density to something like 12 per cent. . . .
>
> In summarizing, two points are to be made: One is the need for more careful observations of snow data, and the other is the risk of assuming a convenient but usually erroneous conversion factor for converting snow depth to water equivalent (3).

Mr. Wilson's final paragraph seems to place the solution of the problem squarely in the hands of the observer. To this, the observer might well reply "Hold on, I have troubles of my own!"



Standard type snow stakes with recommended angle iron supports in center. USWB photo.

Let us consider Mr. Weatherman, a cooperative observer who knows his Circular B by heart and has been measuring the elements conscientiously for twenty years. He has a non-recording gage, the standard 8-inch instrument, and he lives in snow country.

When the radio forecasts tell him that winter's first snowstorm is due, Mr. Weatherman removes the rainfall receiver and measuring tube and stores them away, leaving only the overflow can exposed. In addition, he has snow markers and depth indicators ready for action. The former are usually thin boards, employed to identify the surface of snow after it has been covered by later snowfall. Depth indicators (shown in figure 2) are simply "long-enough" stakes, approximately 1¾ inch square, painted white and set into the ground, to show the height of the snow cover. They are installed vertically, with the zero end resting on the ground, and held in place usually by bolting them to a galvanized steel angle-iron. Mr. Weatherman's gage, markers and indicators are located typically: in an open, level field where no undue effects on the precipitation-catch are expected and where the snow depth is representative of the average cover over the surrounding area.

So it snows. All that morning and afternoon it snows, but it stops—we are assuming an ideal case—just before the 1900 observation so that Mr. Weatherman tramps outdoors under clearing skies and moderating temperatures.

He brings out with him the measuring tube, containing exactly 0.50 inch of warm water, and pours it into the overflow can. When the snow in the can has melted, he pours the contents back into the tube and makes a stick-measurement of 0.77 inch. He promptly notes down the difference between the two values in his "Observer's Notebook": the precipitation amount to be entered on WB Form 612–14 is 0.27 inch.

The actual depth of the snowfall is the next measurement to be taken. Since this is the first snow of the season, Mr. Weatherman does not need to use the markers; but he does place them on the snow surface in preparation for the next observation. His depth indicators give him the desired snowfall value, 3.1 inches, which is also in this ideal case the depth of snow on ground at

observation time. (Of course he reports the latter figure to the nearest whole inch, 3, while he enters the snowfall to tenths.)

Let us consider other conditions and see if Mr. Weatherman's observation proceeds as easily. Suppose he had to be away that day on business; that the snow fell fast and furiously during the late morning hours, followed by rapid clearing and a temperature rise to a maximum around 45°; that Mr. Weatherman returned home just in time to make his evening observation, having been slowed down by the slippery roads.

The indicators show the depth of the snow on ground as 2.8 inches, which is entered as 3, the same as before. But Mr. Weatherman knows that melting and settling of the snow cover have taken place, so that 2.8 inches must be somewhat less than the true fall. He determines the water content of the snow catch in his gage, using the same procedure as in the first case, this time as 0.20 inch.

Mr. Weatherman is not satisfied; he believes that his gage catch was not representative, because the fall was accompanied by strong, gusty winds. So he decides to check the 0.20-inch value by recourse to the sample method. He inverts the empty overflow can and uses the rim to cut several cylindrical vertical samples of the snow on the ground. These he melts down, obtaining an average of 0.25 inch (compared to 0.20 from the gage catch). Following Weather Bureau instructions, he accepts this greater value as the more accurate evaluation of the water equivalent of the snowfall.

If Mr. Weatherman had been careless, a different and misleading set of data could have been obtained. For example, he might have reported the snow depth as 3 inches, the snowfall as 3.0 inches, and the water equivalent (taken from the gage only) as 0.20 inch. Further, if he had not felt like melting the gage catch, he might have used the 10-to-1 ratio and estimated 0.30 inch for the water equivalent. In either case, his precipitation figure would have been in error by 20%.

Fortunately, Mr. Weatherman not only took a good observation in this hypothetical case but continued to make complete and accurate measurements all winter long. Hence, his monthly forms built up year after year an invaluable record on which reliable statistics could be based. His community benefited, for a large ski area was developed on the basis of his snow observations, bringing welcome winter employment to the local residents. Good estimates of the water yield from the snow cover in his drainage basin were made, enabling farmers, hydroelectric interests, operators of factories and mills, to plan their operations. His reports were vital in the issuance of flood bulletins, through which hundreds of valley residents were advised to evacuate or "stay put" with a minimum of unnecessary warnings and a maximum saving in life and property.

Mr. Weatherman was unaware of the many ways in which his observations benefited his fellow citizens. His satisfaction came from doing the job he had undertaken as well as he could.

Perhaps many observers are also unaware of all the uses to which their snow measurements are put. To describe the manifold applications is beyond the scope of this article; merely one illustration may suggest the wealth of information that can be derived from a reliable snowfall record.

This example is drawn from the newly-published *Climatic Guide for Baltimore, Maryland* (7). It was selected with the thought that most people appreciate the significance of snowfall as an important climatic factor in farming and mountain country, or as a weather hazard to inter-state travel and transportation, but dismiss snow in a big city as a mere inconvenience. Figure 3 shows the percentage chance of the first and last snowfalls occurring on any date in Baltimore during the winter. It gives this information for 1-and-3-inch snowfalls: for what may be regarded as "light" and "heavy" snow. Considering the 3-inch occurrences, we can learn the following:

1. The earliest date of the first 3-inch fall (for the period 1898–1955) was October 31st.
2. Its average date (where the 50% line intersects the curve) was January 2nd.
3. Its latest date (where the curve intersects the top of the diagram) was March 30th.

Similarly:

1. The earliest date of the last 3-inch fall was November 10th.
2. Its average date was February 27th.
3. Its latest date was April 19th (approximately).

Moreover, figure 3 tells us that there is only a 10% chance of the first 3-inch fall coming before December 3rd, whereas there is a 20% chance of the first 1-inch fall occurring before that date.

Now, the expense of snow removal represents a sizeable item in the budget of many communities, especially large cities with literally hundreds of miles of streets and highways to clear. Snow-removal equipment is costly; plans must be made to transfer municipal workers from other duties in the event of snow to expedite clearing operations; often additional temporary laborers must be hired. Anyone who has been unfortunate enough to be trapped in traffic when an early-season snow descends upon an unprepared city knows what delays, accidents, losses in time for workers and business establishments, etc., inevitably result.

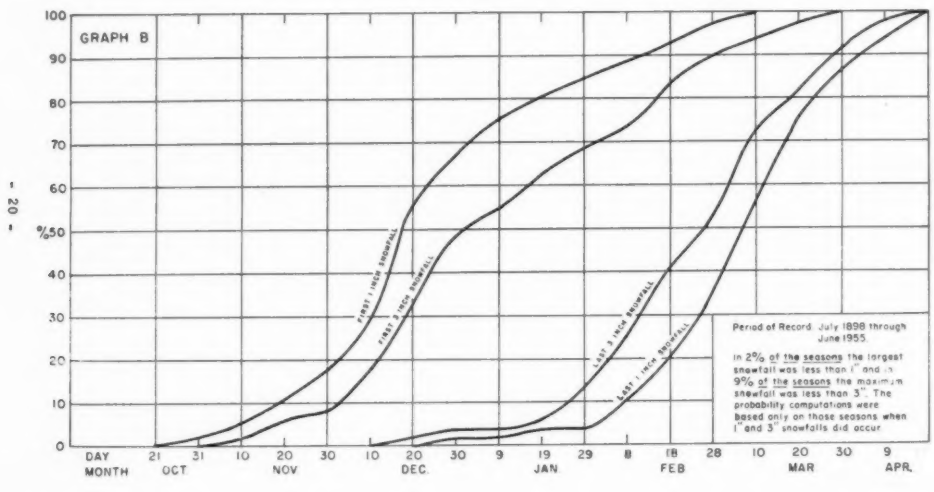
To take a classic case, the nation's greatest city was paralyzed and demoralized when 25.8 inches of snow fell in less than 24 hours on 26–27 December 1947. Of course this was an unexpected, record-breaking snowstorm, not a comparatively minor early-season occurrence, but it dramatizes the effects of snow on a metropolitan area. The Weather Bureau Office in New York City reported afterwards:

> Streets and highways were rendered impassable . . . at least 10,000 automobiles were abandoned . . . bus, trolley, elevated and subway lines were almost totally paralyzed. All airplane flights were suspended, harbor shipping was brought to a virtual halt, and railroad services were cancelled or subjected to long delays. . . . Thousands of commuters were stranded. . . . New York City appropriated almost $7,000,000 in addition to the $1,287,000 regularly alloted for snow removal. . . . The economic loss, direct and indirect, . . . must be measured in the millions of dollars (8).

Of course, no statistics or graphs can predict such a phenomenal event as this. But, with the help of figure 3 and similar climatological aids, municipal authorities, building superintendents, transportation companies, stores large and small—the myriad interests

PRECIPITATION

PERCENTAGE CHANCE OF FIRST AND LAST SNOWFALLS


GRAPH B
100
90
80
70
60
%50
40
30
20
10
0
- 20 -
FIRST 1 INCH SNOWFALL
FIRST 3 INCH SNOWFALL
LAST 3 INCH SNOWFALL
LAST 1 INCH SNOWFALL
Period of Record: July 1898 through June 1955.
In 2% of the seasons the largest snowfall was less than 1" and in 9% of the seasons the maximum snowfall was less than 3". The probability computations were based only on those seasons when 1" and 3" snowfalls did occur.
DAY
MONTH
21 31 10 20 30 10 20 30 9 19 29 8 18 28 10 20 30 9
OCT. NOV. DEC. JAN. FEB. MAR. APR.

affected by snowfall—can plan intelligently and profitably. For example, a Baltimore storekeeper should not mark-down his stock of overshoes at the end of February, for figure 3 reveals there is still a 50–50 chance of one more heavy snowstorm. Also, it would be unwise for the City Fathers to put away the snow-removal machines on March 12th, for there is still one chance in four left that a 3-inch fall will occur. Many more applications might be cited, but it is hoped that the point is sufficiently clear.

If all observers were as diligent as our Mr. Weatherman, or if the Weather Bureau were able to publish "Climatic Guides" for all communities, large and small, snowflakes would pose fewer question-marks. As matters stand, snow data are in such demand for so many varied types of application that the weather records processing centers of the Weather Bureau try to publish a usable record from even incomplete or inconsistent measurements. The personnel at these centers who examine the monthly forms WB 612–14, by recourse to both IBM checking procedures and their knowledge of station exposures and synoptic weather conditions, can often fill in entries left blank by an observer. Such estimates are nevertheless no substitute for the actual measurements; and no reliable estimates can be made when, for example, an observer omits entirely the day-by-day depths of snow on ground or fills in the snowfall values but omits the precipitation equivalents. And an interrupted or incomplete record is difficult to analyze and unreliable with regard to conclusions derived from it.

So, in the last analysis, everything depends upon the observer. He bears a great trust and a greater responsibility, every time he measures snowfall.

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The recording rain gage exposure at Mt. Baker Lodge. Snow depth on 13 April was 252 inches. J. J. Strachila, USWB inspector, is calibrating gage which stands atop an instrument shelter.

Weatherwatch

A Summer of Persistence

DAVID M. LUDLUM, *Editor*

The outstanding feature of the weather regime of Summer 1956 was the persistence of the circulation and weather-type patterns. From mid-June until mid-August the surface and upper-air weather maps of one day resembled in general contours the map of the previous or following days.

On practically all maps during the 60-day period a slow moving, at times stationary, front was found over the Upper South with a general west-to-east or west-to-southeast orientation. The front fluctuated north and south within a limited range—usually remaining well south of the Ohio Valley and well north of the Gulf Coast. Its favorite haunt was over the Carolinas or southern Virginia with a northwestward slant into the middle and upper Mississippi Valley.

This air mass boundary naturally created two distinct temperature zones. In the Deep South this meant a long-continued period of daily maxima near 95° F. The three summer months at all inland points in the South averaged about two degrees above normal. The core of the heat area lay in north-central Texas where readings were plus four degrees. At Fort Worth, Texas, the daily maxima was at or above 100° from 2 to 18 August, and failed to reach the century mark on only five days from 12 July to 18 August. The absolute maximum for July and August 1956 was 107°, well below the all-time maximum of 112° set in 1936. Nevertheless, July was the second hottest seventh-month in the history of the Texas metropolis. At the other end of the South, at Jacksonville, Florida, it was a torrid summer also. With land breezes predominating under an anticyclonic regime the mercury soared above 90° on every day but one from 10 July to 20 August.

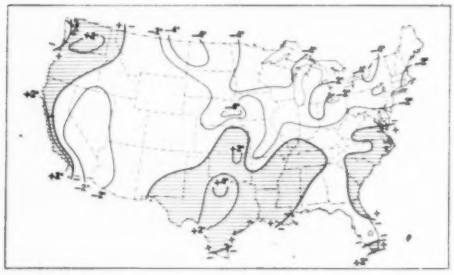
North of the front it was a decidedly different story. The July–August period was one of the most persistently cool summers in recent times. Temperatures averaged as much as four degrees below normal for both months on the Pennsylvania-New York border as cool air mass after cool air mass pushed southeastward out of a reservoir of cold air over central Canada. At S. Ste. Marie in northern Michigan the highest reading for the entire month of July was only 78°. The mercury fell below freezing, to 31°, in the cranberry bogs of Wisconsin on 29 July. Frost and freezing temperatures were widespread in the Northeastern highlands and the interior of the Lakes States during the last ten days of August.

The western anchor of the Upper South front shifted north and south with greater frequency and range in the area west of the Mississippi River. Conditions in the Plains were more varied; there was a gradual expansion of the Southern heat area as the summer progressed through July and most of August. The Rocky Mountain region shared this trend. Though there were many cool days there, the summer averaged out as a little warmer than normal. But the Plateau and Pacific States did not share in the influence of the semi-tropical high over the Southland. Except for the immediate central California coast it was a decidedly cool summer there.

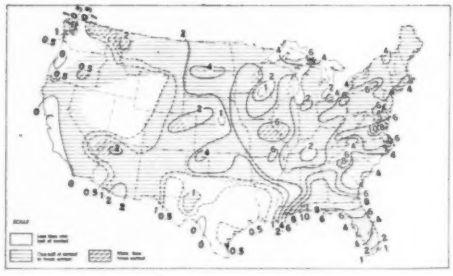
JULY CIRCULATION—The flow of the air streams across the middle areas of the North American continent during July were controlled by two main meteorological features. Across the Gulf of Mexico and surrounding land areas the vast semi-tropical anticyclone, so characteristic of the American summer, was found; it was of slightly greater intensity than usual, and was much more persistent than normal in holding its strength and in maintaining its position.

Far to the north in the immediate polar region, on the longitude of northeast Siberia, there was a very deep low with a minus pressure departure seldom equaled on a summertime map. This induced an

MONTH OF JULY 1956



Departure of Mean Temperature from Normal in degrees F. USWB chart.



Total Precipitation in inches. USWB chart.

active cyclonic season in the Arctic areas of Alaska and Canada eastward to the Atlantic Ocean. The jet stream exhibited two branches, the southern branch, reaching well south of a normal position, was found in the vicinity of 40° N. Latitude at times. Cyclones generated in the polar vortex moved southeastward to central Canada, their trailing fronts dipped into northern United States, and permitted repeated outbreaks of Canadian air to penetrate into the Great Lakes area and the Northeast.

The mean upper-air presure map for July showed a trough extending from the main polar vortex southeastward to a subcenter of low pressure over Quebec-Labrador. A mean trough for July reached southward from central Quebec to Cape Cod and thence southwestward to the Carolinas. The presence of this trough along the Atlantic Coast enticed cool air southward and caused chilly and showery summer weather in the resort areas of the Northeast and Great Lakes. The great anticyclone over the Southeast, however, proved a formidable barrier to the penetration of cool air south of the Ohio Valley. Only one front during the entire month developed sufficient energy to foil the defenses of the high—on 11 July it pushed to the Gulf Coast and into the Atlantic Ocean, giving Jacksonville, Florida, a one day respite from 90° plus readings.

Pressure was generally above normal in the Plateau and Pacific states where an extension of the subtropical high center over Louisiana-Texas dominated the scene. A minor trough appeared off the California coast in July. Its influence on the temperature and precipitation regime is a bit hard to assess. It was warmer than normal on the California coast and in the Northwest, probably due to the southwest circulation on the east side of the trough. Precipitation was normal for summer in its absence.

THE EUROPEAN SUMMER—An interesting feature on the Northern Hemisphere mean pressure map for July appeared in the Ural Mountains area of the Soviet Union. An unusually deep low pressure center with unusually cold air was centered there for the greater part of the month. Westward upstream from this deep vortex, another trough at short wavelength was located from Iceland to Great Britain. Thus, cold air flowed easily southward from the Arctic over the British Isles and western Europe, resulting in a summer notably lacking in warmth and sunshine. It would appear that the elements conspired to produce just the opposite of the extremely pleasant 1955 season for European vacationers.

AUGUST CIRCULATION—The first two weeks of August continued the general circulation and the resultant weather patterns which had marked the previous six weeks. It was hot in the South, cool in the North, and changeable with a trend toward lower temperatures in the West. Throughout the Dog Days of early August, the semi-tropical anticyclone with a main center over the mid-Atlantic and a secondary center over Texas held the almost stationary front across the Upper South, preventing any significant interchange of air masses. It continued the western trough-central ridge-eastern trough arrangement across the continent.

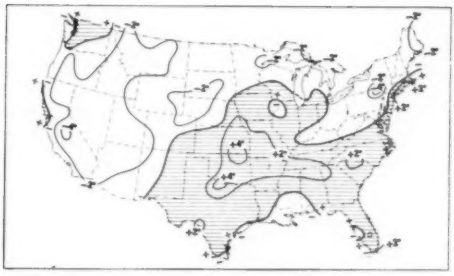
Toward mid-August, however, things began to happen on the weather map of North America. On the 12th the second tropical storm of the season, Hurricane Betsy, crossed Puerto Rico with severe local damage. At the same time a deep polar low with a closed circulation well above 20,000 feet made an appearance in the Canadian Northwest. This disturbance was accompanied by an active surface circulation which introduced the first winter-like air mass from the polar regions to the interior of central North America. The main low moved rather slowly southeastward with deep cold air in its western side, taking a full week to cross Hudson Bay and to clear the Labrador coast. Meantime, Betsy had moved somewhat sluggishly northeastward, hesitated in the Bahamas, and then moved northward and finally northeastward to join in the polar trough of the Canadian low.

The circulation stirred up by these two disturbances at opposite ends of the North American continent changed the weather picture of the entire country. The summer regime ended, and a flow pattern much more reminiscent of autumn took over.

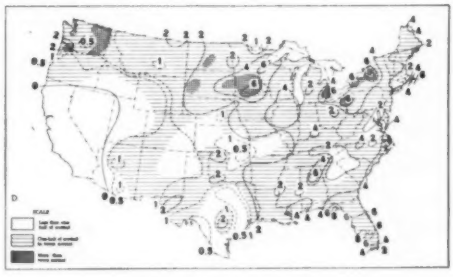
The coast of eastern United States was the scene of trough action. Practically all the depressions noted on the weather maps of the country in August existed during the latter fifteen days of the month. The eastern trough, at times, reached from polar regions to the Gulf of Mexico; it enabled cool air masses to penetrate all the way to Florida, to give relief to all the Southland after an eight-week seige of hot weather.

The large semi-tropical anticyclone shifted its main strength westward as Betsy approached from the Southeast, and thereafter was found in a position over New Mexico and Arizona after the 15th. A western ridge-eastern trough regime dominated for a week until another trough appeared along the Pacific Coast and cyclonic activity became marked in

MONTH OF AUGUST 1956



Departure of Mean Temperature from Normal in degrees F. USWB chart.



Total Precipitation in inches. USWB chart.

the Northwest, always a harbinger of the cold season.

HURRICANE BETSY—The major weather event of the month was the threat that Hurricane Betsy threw at the southeastern coastline of the United States in the middle days of August. Florida had not been seriously threatened with hurricane force winds since October 1950 when a small storm of hurricane stature hit the Miami area from the south. The progress of Betsy from its discovery on 10 August until it reached the northern Bahamas on the 15th kept much of the mainland coast on the alert. Betsy's first landfall was on Puerto Rico on the 12th where she cut a 20-mile swath of severe structural damage across the heart of the island from southeast to northwest. The Red Cross reported that 13,559 houses were destroyed by this edition of tropical fury and that 37,007 houses were seriously damaged in the 56 communities seriously affected. The Puerto Rico Government estimated that the damage figure would reach $30 million. Housing and feeding the victims became a major problem and taxed relief facilities on both the island and the mainland.

Betsy followed the familiar hurricane alley through the warm waters of the Bahamas Group with the center of the disturbance passing just to the northeast of all major islands. After reaching latitude 23° N about 350 miles east of Melbourne, Florida, she hesitated during the 14–15th, so as to permit the Hurricane Research Center to get a good look at her structure, and then, recurving, set off on a north-northeast course looping away from the mainland. When off the Virginia Capes in Latitude 37 N. on the 16th, the central pressure was estimated at 957 mb (28.25″). After another short period of hesitation, Betsy moved at a rapid pace as she encountered a strong westerly current aloft and rushed with extra-tropical speed northeastward in the warm waters of the Gulf Stream.

CROP PROSPECTS—The end of August found the Nation's agricultural prospects, as regards the progress of crops and harvests, in good condition. Although politicians were taking opposite views of the status of the farmer, those who surveyed the season's crops generally agreed that 1956 would be a very productive year on the acreage planted. Unlike the previous summers since 1952, there were only two limited areas that suffered from moisture deficiency in a serious way. The Gulf States, under the hold of the tropical anticyclone, had been dry during July and much of August. Cotton, peanuts, corn, and citrus suffered there, but the situation was greatly improved by late August rains. An increasing droughty situation affected the middle Great Plains and threatened to hold up fall plantings. The most serious situation continued from previous months in the Plateau of central and west Texas and in the Rio Grande Valley. In many places no rain fell during the three summer months.

Elsewhere moisture was in relatively good supply. New England recovered from an early dry period in July. Through the Middle Atlantic States, the Ohio Valley, and the upper Mississippi Valley, crop prospects appeared excellent. In the Northeast frequent showers kept grains and fruit in good shape. In the Far Southwest the sunny skies favored irrigated crops. An excellent yield was in prospect for the Imperial Valley of California and other vegetable-raising areas as the month of August drew to a close.

Waterspouts Off Cape Cod

9 September 1956

THROOP SMITH, *Concord, Mass.*

Date: 9 September; time of occurrence: 1300 EDT. While I was on Nauset Beach on Cape Cod, Massachusetts, right across from Chatham, I noticed two waterspouts one to two miles out to sea. Neither of the spouts touched the water, but directly below them there was a column of spray rising 10 to 20 feet. The small waterspout was not well formed, and it dissipated and started again twice during the 15 minutes that we watched it. The large one stayed pretty much the same and lasted longer than the smaller one.

The cloud from which the waterspouts came was only a cumulus congestus, covering a fairly small area, for we did not get any rain. Off in the distance there were other clouds of the same size, all connected by a layer of altocumulus. No lightning was visible.

Fred Lund III, also, saw these waterspouts, and one more, to the NNE, ENE, and E of Chatham from 1230 to 1257. A very thin one extended one-third to possibly one-half way from cloud to sea, the other two only about one-fifth. There was an unstable dry air mass with many showers, some of them very heavy that afternoon, a whole series coming from the north.

According to USWB reports, waterspouts were also seen at Nantucket Island, 20 miles south of Chatham.

Comment: The failure of the waterspout cloud column to reach the sea surface, even though the whirling winds did, may be ascribed to low relative humidity and moderate intensity of the whirlwinds. At Blue Hill Observatory, 70 miles NW of Chatham, at 1300 the temperature was 60° F., dew point 45°, and relative humidity 56%. By dew-point formula the bases of the cumulus congestus clouds were at 4,000 feet above sea level, and by proportion their tops at 9,200 feet. The bases were moving from N by W and the tops NE by E, both at 10 mph. The surface wind was NE at 10 mph. If the cloud base off Chatham was at 3,000 feet, the

whirling was strong enough to lower the pressure sufficiently to bring the condensation level in a spout down about 1,000 feet, which would correspond to about a 45 mb, or a little over one inch, pressure reduction.

CHARLES F. BROOKS.

Agricultural Climatology in the Northeast

A. VAUGHAN HAVENS, *Dept. of Meteorology, Rutgers State University*

Interest and activity in Agricultural Climatology in the Northeast has increased considerably with the recent activation of a Regional Research Project titled "The Application of Climatology to Northeastern Agriculture." The project is being conducted by the several State Agricultural Experiment Stations in the Northeast in cooperation with the U. S. Department of Agriculture and the U. S. Weather Bureau.

One of the principal objectives of this project is to place on punched-cards the historical weather records dating back to 1926 for a large number of cooperative weather stations. This will make possible the statistical analyses of temperature and rainfall data for the Northeast in such a way as to make these data much more useful to agriculture. The time and personnel required to make these analyses without the aid of punched-cards and machine methods of tabulation and computation would be practically prohibitive.

This phase of the project is being closely coordinated with the Office of Climatology and the National Weather Records Center of the U. S. Weather Bureau.

A second major objective of the project is to stimulate experimentation that will further knowledge of the relationships between microclimate and agriculture.

Over-all direction and coordination of the work being carried on under this project is the responsibility of the Northeastern Technical Committee on Agricultural Climatology which is made up of representatives from each of the cooperating organizations.

At their organizational meeting in February of this year, the group elected as chairman, Dr. A. E. Dimond, chief of Plant Pathology and Botany at the Connecticut Agricultural Experiment Station in New Haven; and A. V. Havens, associate professor of Meteorology at Rutgers University, was appointed as secretary. Dr. A. A. Spielman, associate director of the Agricultural Experiment Station at Storrs, Connecticut, is the administrative advisor. J. K. McGuire, area climatologist for the Northeast, is the Weather Bureau representative on the Technical Committee.

The Technical Committee met on September 6–7th of this year at the University of Maryland for the purpose of standardizing within the Northeast the summarization of temperature and precipitation data from the punched-cards. Mr. Paul Kutschenreuter represented the Chief of the U. S. Weather Bureau at this meeting and addressed the group on the Weather Bureau's role in agricultural meteorology and climatology. Dr. Thomas F. Malone, director of the Travelers Weather Research Center, also attended the meetings and offered many helpful suggestions. In addition, technical assistance was provided by representatives of the Office of Climatology, the Agricultural Research Service, and the University of Maryland.

Although this project was established primarily to further agricultural climatology in the Northeast, it is very likely that many benefits in related fields may be realized as indirect results.

One important by-product of the project stems directly from the cooperative agreements between the Weather Bureau and the States under which the punching is accomplished. In this way, the National Weather Records Center is also provided with punched-card data extending back to 1926 for all the stations concerned.

These punched-card records will undoubtedly be useful for many applications of climatology to industry, commerce, and public health as well as agriculture, not only in the States concerned but also at the national level by the NWRC.

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Solar Research

(*Continued from page 157*)

But these are the unavoidable conditions of life at Climax, with its improbable amalgam of opposites, clear sky and frequent precipitation, combined with high altitude—all of which aid in producing good coronal observing. At Climax the cleanest air comes after a few hours or a few days of steady gentle precipitation, which up there usually means snow. The worst atmospheric halos come, understandably, after dry spells and with wind. Sometimes favorable local conditions are overweighed by large-scale atmospheric problems, however, such as widespread cirrus or extensive forest fires in the Pacific Northwest.

Most of the time, and particularly in summer when the ground is bare, the observers hope for clear mornings, with time to obtain their coronal observations; but they also hope for cloud-up late in the day with eventual rain, preferably after sunset (though it usually comes earlier), so that next morning's sky will be rain-washed. The ideal usually eludes them, but they meet it frequently enough to make the station highly valuable. In fact, they are able to observe the sun's corona on about 60 per cent of all days, and on about 10 to 15 per cent of the days conditions are really excellent for an hour or more.

High level stations in the Pacific, such as Mauna Loa or Mount Haleakala in the Hawaiian Islands, because of the frequent dust-confining inversion and the high percentage of clear sky, might offer even higher promise for coronal research. In any event, research on the sun's faint atmosphere will for a long time find us struggling with the limitations of looking through a contaminated terrestrial atmosphere. Someday, perhaps, we shall be able cast off our earthly shackles, and operate a coronagraph from an artificial satellite; but that is far beyond the drafting boards of today.

Meanwhile, at a half-dozen or so coronagraph stations scattered over the globe, isolated observers go about their business in the next-best way. From their efforts a new field of knowledge opens before us.

Highs and Lows

(*Continued from page 161*)

lantic into North Africa and a primary through the Middle Atlantic States towards Bermuda and then eastward across the Atlantic between 30° and 35° N.

Perhaps the outstanding feature of December is continued intensification of anticyclonic activity in the Great Basin. In 5° quadrangles within this area, both the number of days with high centers and the frequency of anticyclogenesis are absolute maxima for any month and any place. In this connection, it is worth recalling that the highest absolute frequency of cyclones also occurred during December, in the Gulf of Alaska. A close relation between these two centers of action, the Gulf of Alaska Low and the Great Basin High, has long been known to exist.

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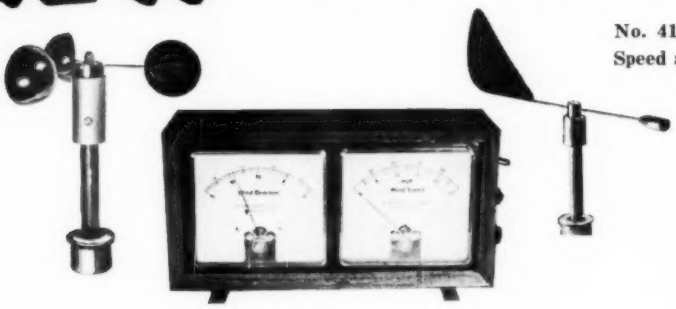

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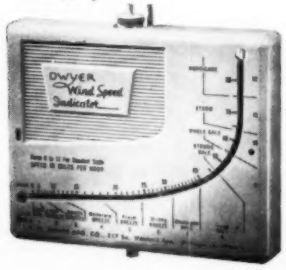

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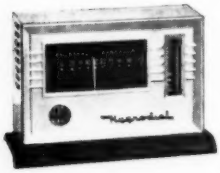

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